



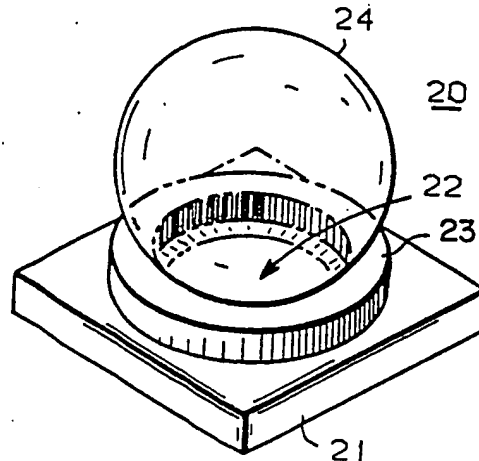
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(54) Title: LED HAVING SELF-ALIGNED LENS

(57) Abstract

A relatively thick ring (23) of polymer or metal encircles the emitting area (22) of a light emitting diode. A spherical lens (24) rests on the ring and is both accurately located with respect to and spaced from the emitting area.



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LED HAVING SELF-ALIGNED LENS

Background of the Invention

5 This invention relates to electro-optical devices having a photo-active area such as light emitting diodes (LEDs) and photodetectors and, in particular, to LEDs and photodetectors having an integral lens. As used herein, "light" refers to electromagnetic radiation which
10 semiconductor material can be caused to emit or detect, whether or not such emission is visible to the unaided human eye.

A number of LED devices have been proposed in the prior art in which a lens is attached or located adjacent
15 the light emitting area of the diode. Since the lens has an approximate focal zone, it is important that the lens be accurately located so that the focal zone coincides with the emitting area of the diode. This entails a careful positioning of the lens in three dimensions. In the past,
20 the emitting area is coated and a lens is rested on the liquid coating. The lens is then moved about while the LED is turned on in order to find the optimum position. This approach is tedious, time consuming, and costly. Further, since even slight lateral displacement (parallel to the
25 plane of the emitting area) causes large changes in the amount of light coupled, performance specifications of the LED are difficult to achieve consistently. A smaller, but not insignificant, variation is caused by variation from device to device in thickness of the coating. An
30 alternative procedure is to align the lens visually over the device's emission area.

It is, therefore, an object of the present invention to provide an LED having a lens accurately located in three dimensions with respect to the emitting area of the diode.

35 Another object of the present invention is to provide

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A further object of the present invention is to provide an improved method for manufacturing LED's with lenses.

Another object of the present invention is to provide
5 an improved LED structure so that lenses can be attached prior to the diodes being separated from the wafer.

Summary of the Invention

10 The foregoing objects are achieved in the present invention wherein a ring of material is formed surrounding the emitting area of the LED. Controlling the thickness and aperture of the ring provides an accurate spacing between the lens and the emitting area. The aperture in
15 the ring also laterally locates the lens. The ring is formed by coating the LED and patterning the coating to leave a ring about the active area. The coating may comprise diverse materials such as metal and/or polymers such as photoresist and polyimides.

20 A more complete understanding of the present invention can be obtained by considering the following detailed description in conjunction with the accompanying drawings, in which:

25 Brief Description of the Drawings

FIGURE 1 illustrates an LED with lens in accordance with the prior art.

FIGURE 2 illustrates a preferred embodiment of an LED
30 with lens in accordance with the present invention.

FIGURE 3 illustrates a sequence of steps for assembling an LED and lens in accordance with the present invention.

FIGURE 4 illustrates a packaged LED in accordance with
35 the present invention.

Detailed Description of the Invention

In accordance with the prior art, as illustrated in FIG. 1; a semiconductor body 11 comprises a photo-emitting area 12. Semiconductor body 11 may comprise any suitable material such as gallium arsenide or, more particularly, what is known in the art as a heterojunction device comprising several doped layers of gallium arsenide. As known in the art, the flow of electric current through the junction in these devices causes the "active" layer to emit photons, the energy of which is within a relatively narrow band of frequencies, giving the LED its characteristic color. The electrical leads and connections by which current is caused to flow through the junction have been omitted for clarity.

Since the emission of photons by emitting area 12 is characterized by what is known as Lambertian emission, it is desired to gather as much of the emitted light as possible and redirect it into a preferred direction. To do this a spherical lens 14 is positioned over emitting area 12 and held in place by a suitable adhesive 13. As with any lens, it is extremely important that the photo-emitting area be within the focal zone of the lens. This requires that the lens be accurately positioned with respect to emitting area 12. As illustrated in FIG. 1, emitting area 12 is shown considerably larger than it would be in an actual device. For example, emitting area 12 typically has a diameter of about 50-100 micrometers while spherical lens 14 typically has a diameter of 250 to 380 micrometers. Thus, any lateral misalignment of lens 14 with respect to emitting area 12 causes a considerable decrease in the amount of light gathered by lens 14. In the prior art, adhesive 13 is typically applied to the upper surface of semiconductor device 11 and lens 14 is positioned over emitting area 12. Lens 14 is then held in place until

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alignment of lens 14. Lens 14 is typically aligned with emitting area 12 either visually or by passing a current through the device and monitoring the light output. The former technique is inaccurate while the latter technique
5 is time consuming and costly, and is subject to problems of consistency since the alignment is being done by hand.

In accordance with the present invention, as illustrated in FIG. 2, light emitting semiconductor 21 having light emitting area 22 is provided with step 23
10 surrounding light emitting area 22. Step 23 is formed by depositing layer over the upper surface of semiconductor 21 and then patterning and etching the layer. Since step 23 is formed with light emitting semiconductor 21 using
15 precise optical techniques, the alignment of ring 23 with light emitting area 22 is quite accurate and subject to the same tolerances as for the formation of light emitting area 22. Lens 24 is then readily located by step 23 and is accurately positioned laterally with respect to emitting area 22 as well as being accurately spaced therefrom.
20 Inserting lens 24 into the center portion of step 23 requires little precision and does not require the activation of the LED. Thus, the LED and lens can be assembled in batch form, i.e. requiring the handling of wafers rather than individual die. This further simplifies the assembly
25 of an LED and lens and further decreases the cost of the assembly.

Lens 24 can have any suitable lenticular shape and comprise any transparent, high index of refraction material which will not contaminate the diode. Suitable materials
30 include glass and minerals such as sapphire and GaP. In a preferred embodiment of the present invention, spherical glass beads are used since they are abundantly available at relatively low cost.

As illustrated in detail in FIG. 3, device 21 with
35 photo-active area 22 is covered by one or more layers 27

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which are then patterned and etched to form step 23. Lens 24 is then rested on step 23 and automatically aligned and separated from emitting area 22 by step 23. Finally, a suitable adhesive 28, such as GE-261 or Hysol OS-1600, is disposed about step 23 to secure lens 24 to step 23 and to light emitting semiconductor device 21. The adhesive is then cured by the application of heat.

An additional advantage in the structure of the present invention can be obtained by interchanging the last two process steps. Specifically, uncured adhesive 28 is first applied over and about step 23 and then lens 24 is brought into contact with adhesive 28. Since surface tension forces in adhesive 28 considerably exceed the weight of lens 24, a self-centering action takes place whereby the adhesive positions and holds lens 24 in a central location with respect to step 23. This technique further adapts the present invention to batch handling of devices rather than individual handling of devices. Despite such simplification, however, lens 24 is much more accurately and consistently aligned with emitting area 22 than has been obtainable in the prior art.

Layer 27 may comprise any suitable material, for example, a metal layer, a thick layer of photoresist, or both. If layer 27 is in the form of a ring or other closed figure, it is preferred that thick metal not contact the semiconductor surface due to the large difference in thermal coefficients of expansion between most common metals and the semiconductor. Any thick photoresist material can be used for layer 27. For example, a photo polymer film resist sold under the tradename "RISTON" by E.I. DuPont de Nemours & Co. has been found suitable for use in the present invention. For example, following the manufacturer's directions, a 0.1 mm layer of Riston is applied to semiconductor 21 and patterned to form step 23.

FIGURE 4 illustrates a complete device in what is known as a TO-92 type package. Specifically, header 41

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comprises a formed metal blank having appropriate leads adjacent thereto which provides support and electrical and thermal contact to semiconductor die 21. Semiconductor die 21 is attached to header 41 by any suitable means, e.g. soft or hard solder or conductive epoxy. As known in the art, if it is desired to electrically isolate die 21 from header 41, a wafer of electrically insulating ceramic, such as beryllium oxide, can be interposed between the die and header. Step 23 on die 21 locates and separates lens 24 from die 21. Surrounding and enclosing die 21 and lens 24 is encapsulant 42, preferably comprising a colorless polymer, having flat surface 43 which acts as a window.

In operation, current through the LED causes light to be emitted. The light radiating upward is gathered by lens 24 and projected through surface 43. This light is viewed or used directly or can be coupled into an optical fiber transmission line for use at a remote location.

Having thus described the invention it will be apparent to those of skill in the art that various modifications can be made within the spirit and scope of the present invention. For example, one need not completely etch away layer 27 to form step 23 in the shape of an annular ring, but could simply form the central aperture only, leaving the rest of the layer as a protective coating. Further, the alignment and spacing need not be accomplished by use of a closed geometry since, as known per se in the art, only three supporting points are actually necessary to space and align lens 24. However, particularly for gallium arsenide devices, the crystal structure of the light emitting diode is sensitive to dislocations. Only three supporting points may cause excessive stress in the gallium arsenide. Step 23 in the form of a ring provides a protective function as well in spacing lens 24 away from the surface of semiconductor 21. The LED itself may comprise either planar or "etched well"

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In present etched well devices, the well tends to be too wide and too deep for the step to be added to the edge of the well. Forming the step in the well would cure this problem. While described in a preferred embodiment as a
5 light emitting device, the present invention can also be embodied in light detecting devices. Also, depending on the adhesive chosen, any suitable cure can be effected, e.g. thermal or actinic radiation.

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Claims

1. An electro-optical semiconductor device comprising:
 - 5 a semiconductive substrate having a photo-active area;
 - a lens separated from and approximately centered over said light emitting area; and
 - step means on a surface of said substrate and
 - 10 between said lens and said substrate, said step means defining an aperture coincident with said area and smaller than the diameter of said lens.
2. The device as set forth in claim 1 wherein said
- 15 step means comprises an annular ring on said surface.
3. The device as set forth in claim 2 wherein said ring comprises photoresist polymer.
- 20 4. The device as set forth in claim 2 wherein said ring comprises a metal layer.
5. The device as set forth in claim 1 wherein said lens comprises a spherical lens.
- 25 6. The device as set forth in claim 5 wherein said lens comprises glass.
7. The device as set forth in claim 1 and further
- 30 comprising adhesive means for attaching said lens to said step means.
8. A method for assembling a lens and a semiconductor device having a light emitting area comprising the
- 35 steps of:

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forming a layer of predetermined thickness on
said device;

patterning said layer to form an aperture at
least as large as said area and in approximate registration
5 therewith; and

attaching said lens to device by locating said
lens in said aperture.

9. The method as set forth in claim 8 wherein said
10 attaching step includes the step of securing the lens to
said device with adhesive.

10. The method as set forth in claim 8 wherein said
attaching step comprises the steps of:
15 depositing adhesive on said layer and said area;
contacting said adhesive with said lens whereby
surface tension forces cause a self-centering of the lens
over said area; and
gelling said adhesive thereby locking the lens in
20 position over the LED.

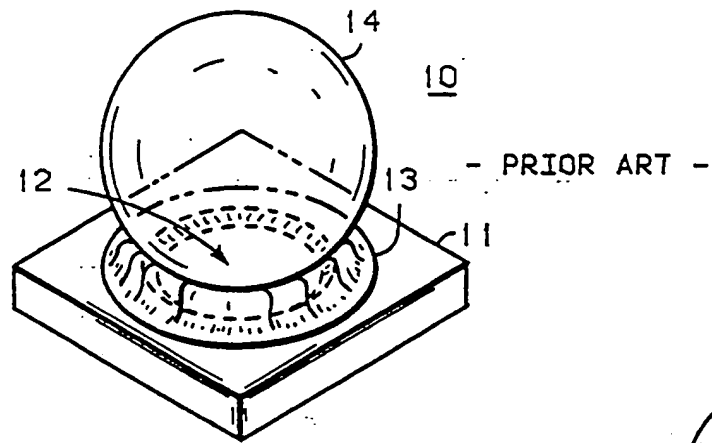


FIG 1

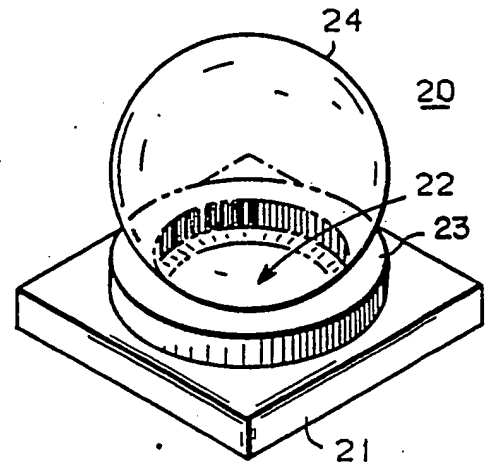


FIG 2

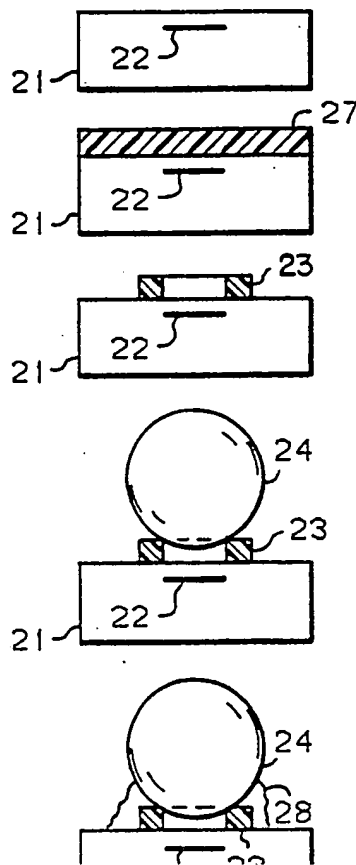
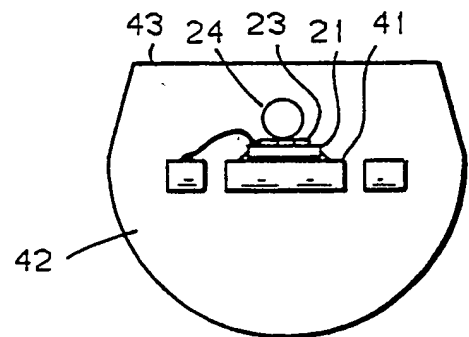


FIG 3



INTERNATIONAL SEARCH REPORT

International Application No PCT/US82/00589

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl. ³ H01L 33/00 U.S. Cl. 357/17		
II. FIELDS SEARCHED		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
US	357/17, 72, 30; 350/96.20; 156/158, 60; 29/569L	
Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched *		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category *	Citation of Document, ¹⁵ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	<u>Electronics</u> , Vol. 52, No. 11, 24 MAY 1979, pp. 73-74. Note Fig. 3.	1, 5, 7, 8
Y,E	US, A, 4,329,190, Published 11 MAY 1982,	9, 10
Y	US, A, 3,816,847, Published 11 JUNE 1974	1, 2, 5, 8
A	US, A, 3,764,862, Published 09 OCTOBER 1973	
A	US, A, 3,834,883, Published 10 SEPTEMBER 1974	
Y	US, A, 3,932,881, Published 13 JANUARY 1976	1
<p>* Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search *	Date of Mailing of this International Search Report *	
08 September 1982	17 SEP 1982	
International Searching Authority *	Signature of Authorized Officer ¹⁹	
ISA/US	M. Edlow	

PCT/ISA (1982) (second sheet) (October 1981)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE ¹⁰

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter ¹² not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out ¹³, specifically:

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING ¹¹

This International Searching Authority found multiple inventions in this international application as follows:

I. Claims 1-7, directed to a product

II. Claims 8-10, directed to a process

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☒ No protest accompanied the payment of additional search fees.